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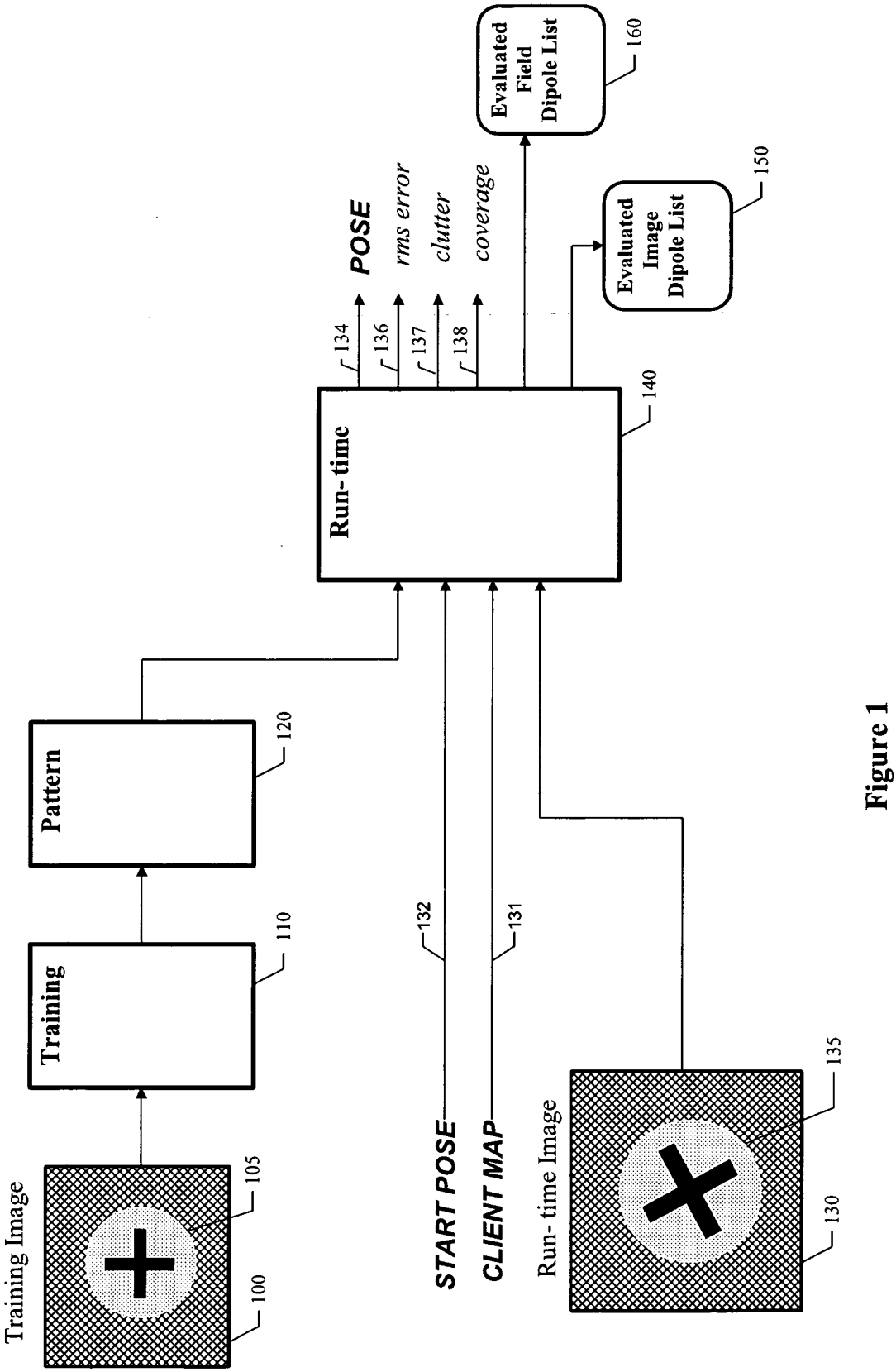

Figure 1

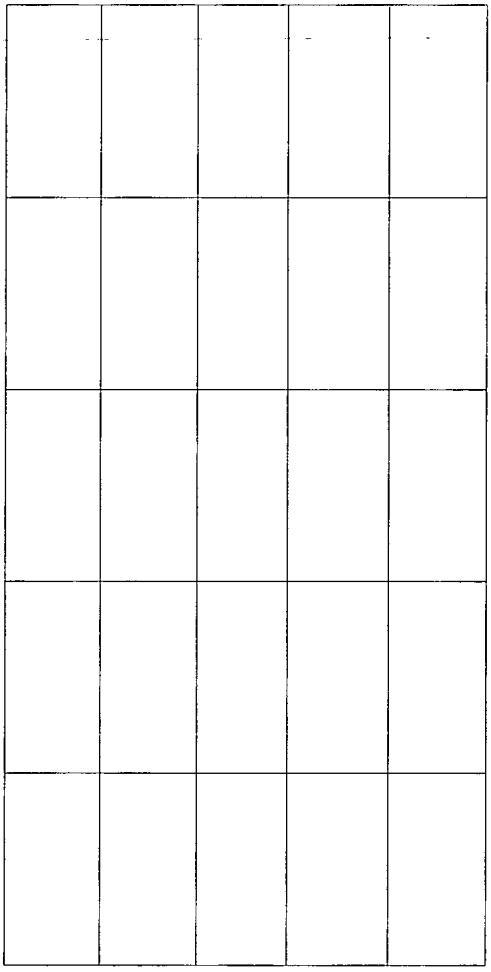

Figure 1A

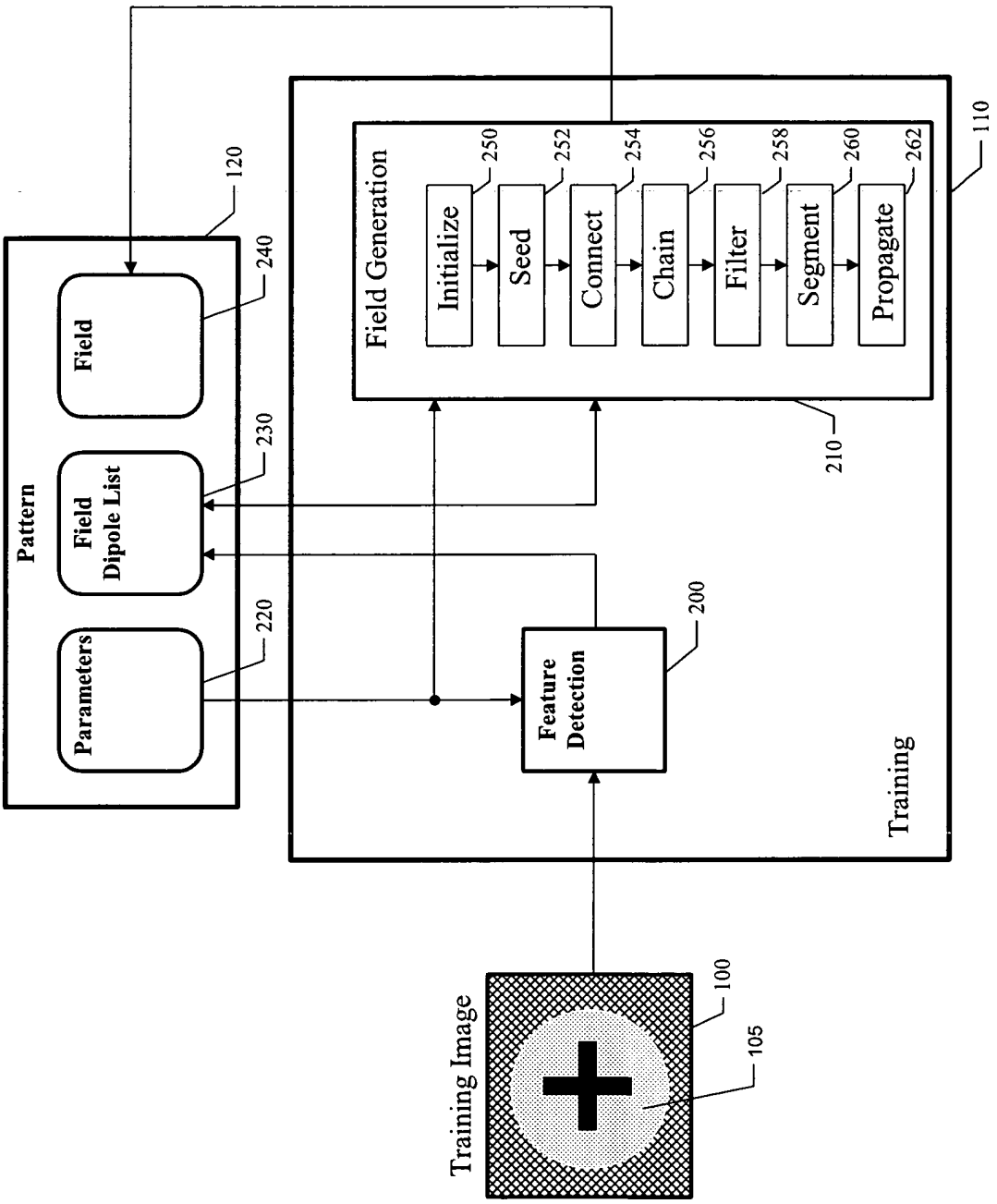
Training Image
100
105
Training
110
Field Generation
Initialize
250
Seed
252
Connect
254
Chain
256
Filter
258
Segment
260
Propagate
262
210
Feature Detection
200
Pattern
120
Field
240
Field Dipole List
230
Parameters
220

Figure 2

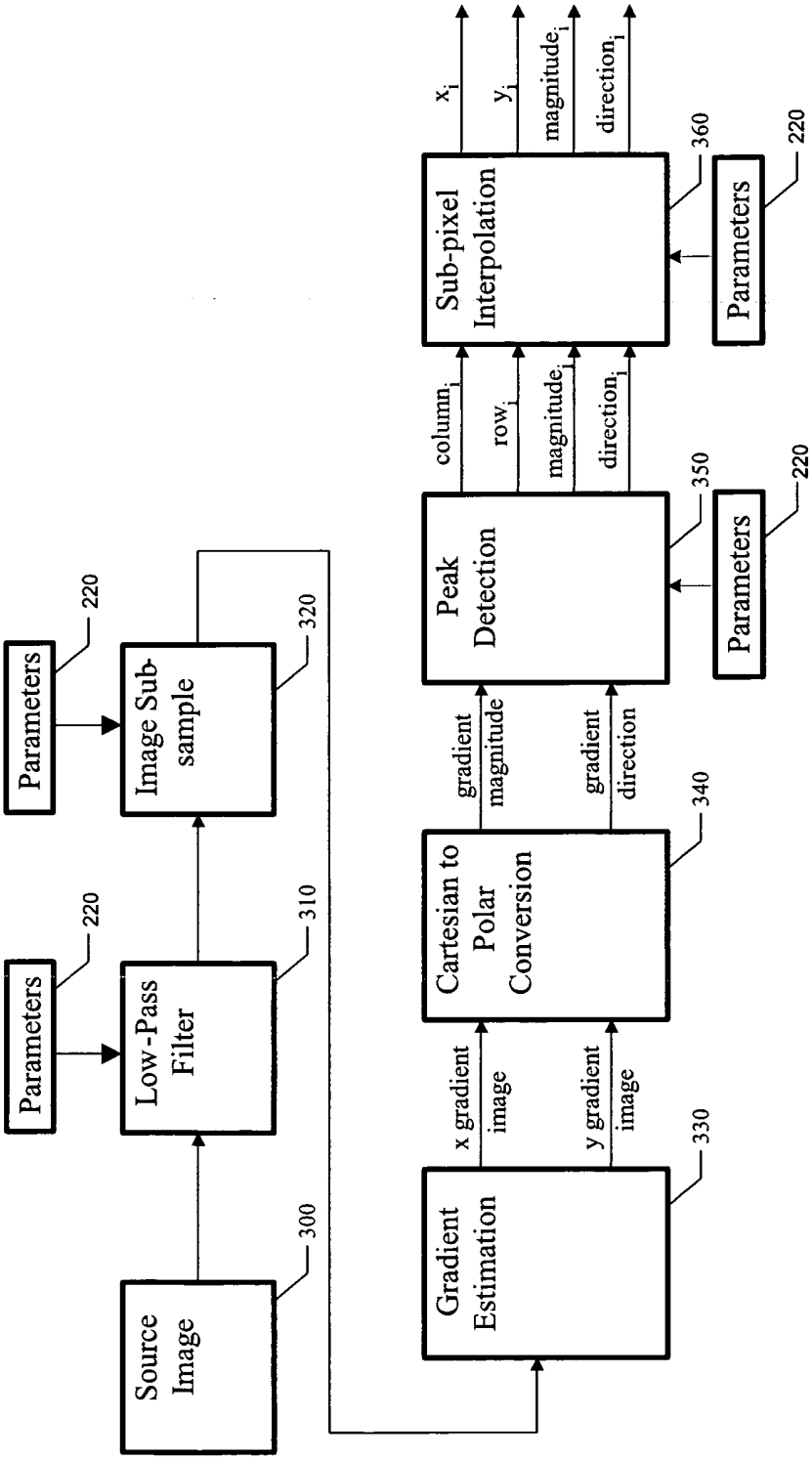
Source Image
300
Low-Pass Filter
310
Image Sub-sample
320
Gradient Estimation
330
Cartesian to Polar Conversion
340
Peak Detection
350
Sub-pixel Interpolation
360
Parameters
220
x gradient image
y gradient image
gradient magnitude
gradient direction
column_i
row_i
magnitude_i
direction_i
x_i
y_i
magnitude_i
direction_i

Figure 3

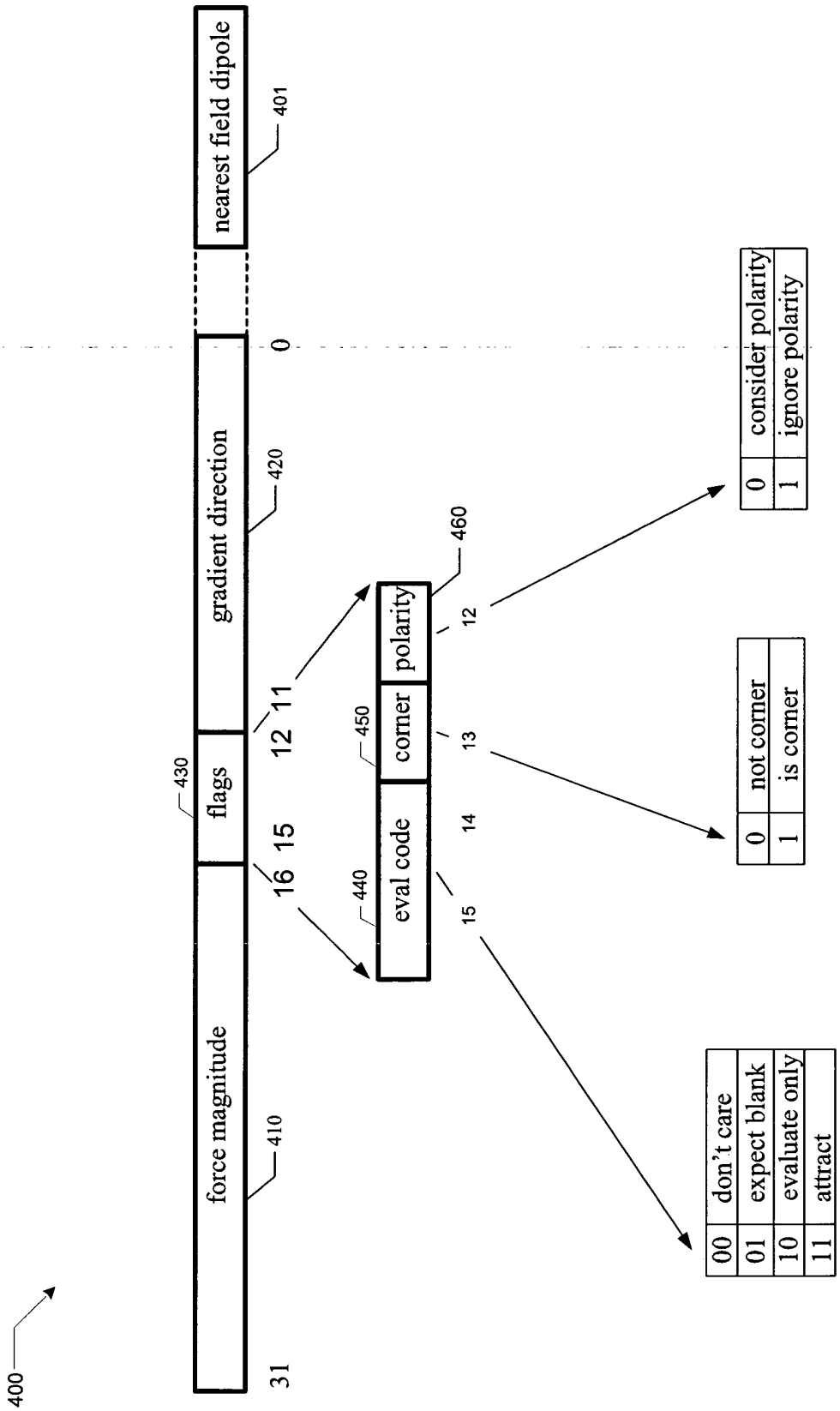
400
force magnitude
410
31
flags
430
16 15
eval code
440
corner
450
polarity
460
12 11
gradient direction
420
0
nearest field dipole
401
00 don't care
01 expect blank
10 evaluate only
11 attract
15
14
13
12
0 not corner
1 is corner
0 consider polarity
1 ignore polarity

Figure 4

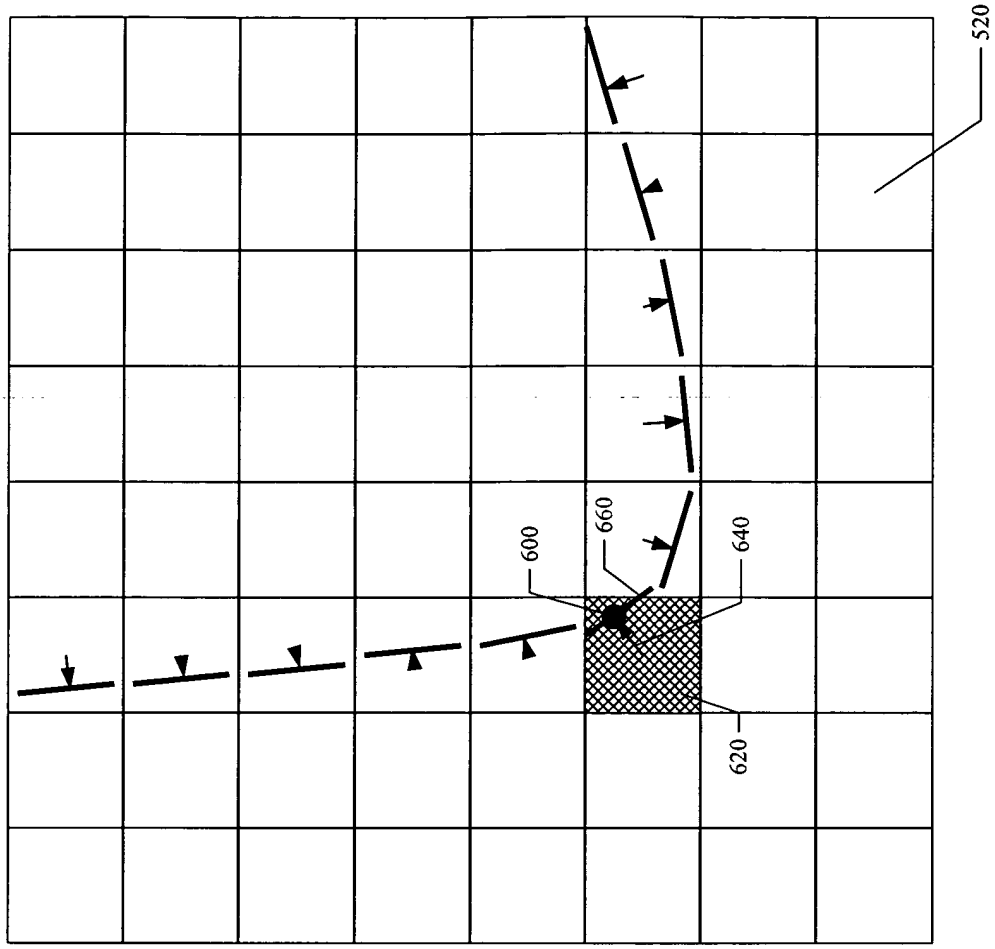

Figure 6

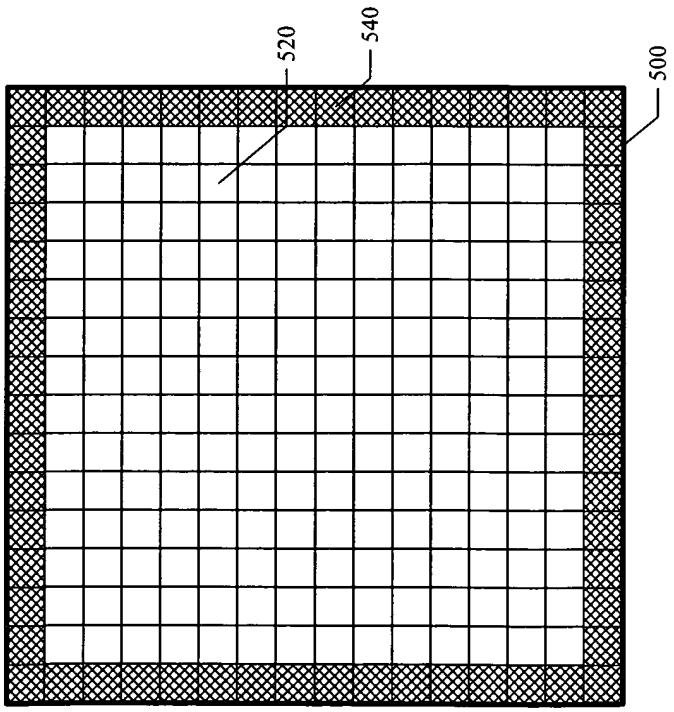

Figure 5

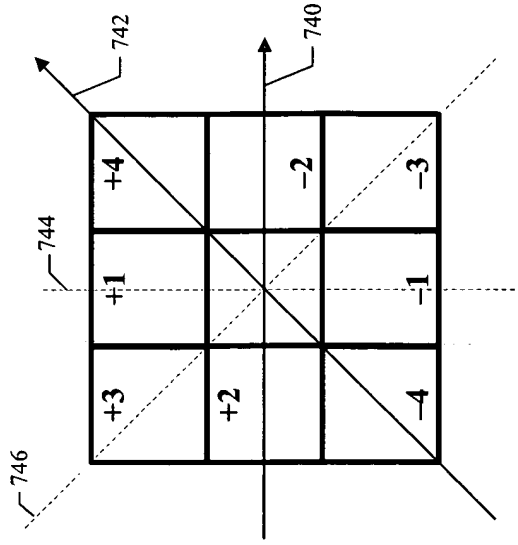

Figure 7b

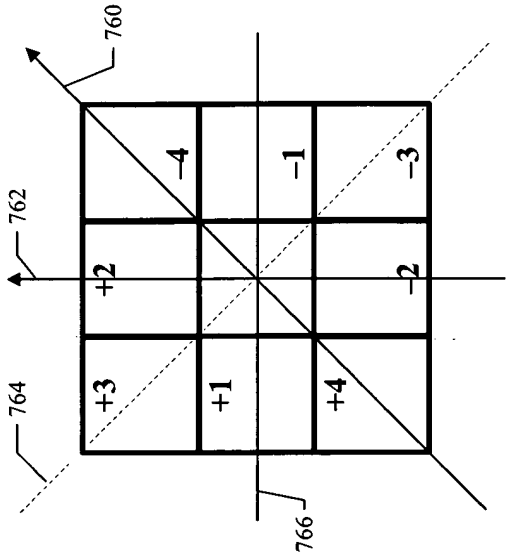

Figure 7c

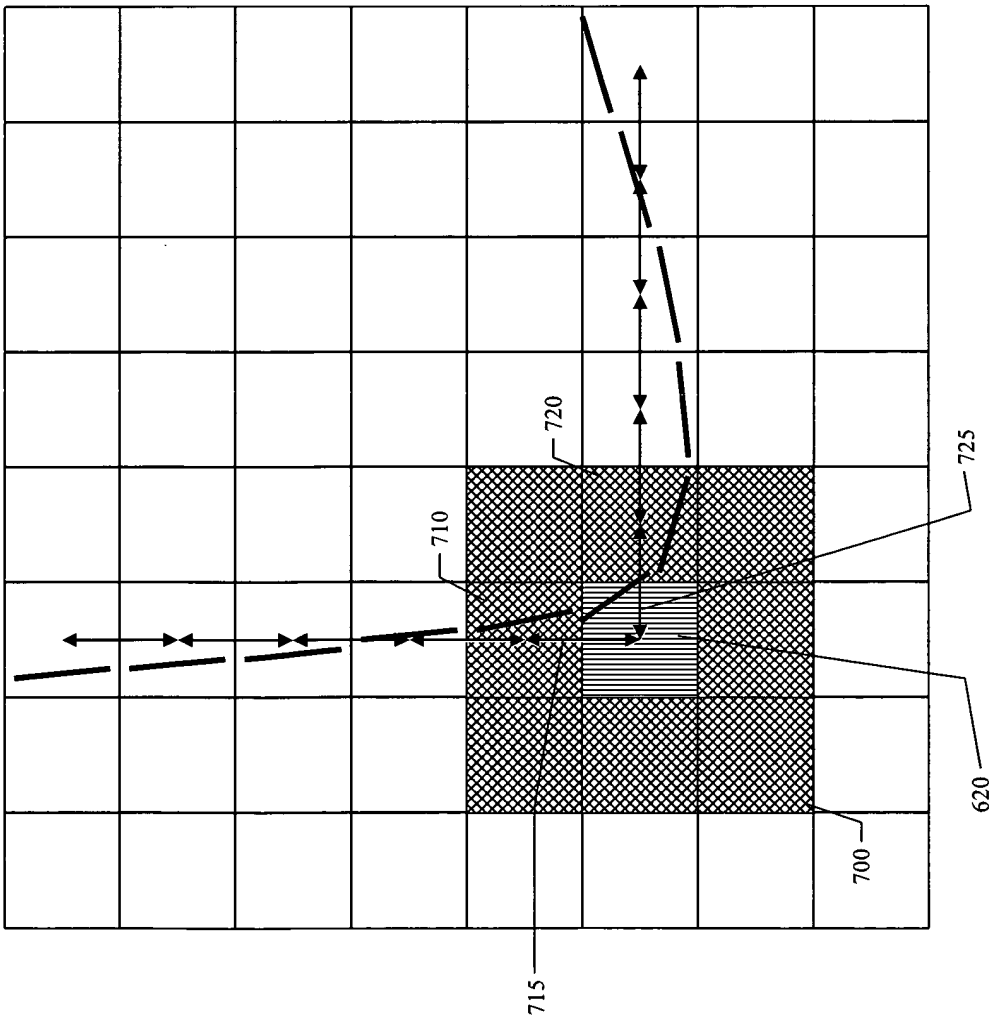

Figure 7a

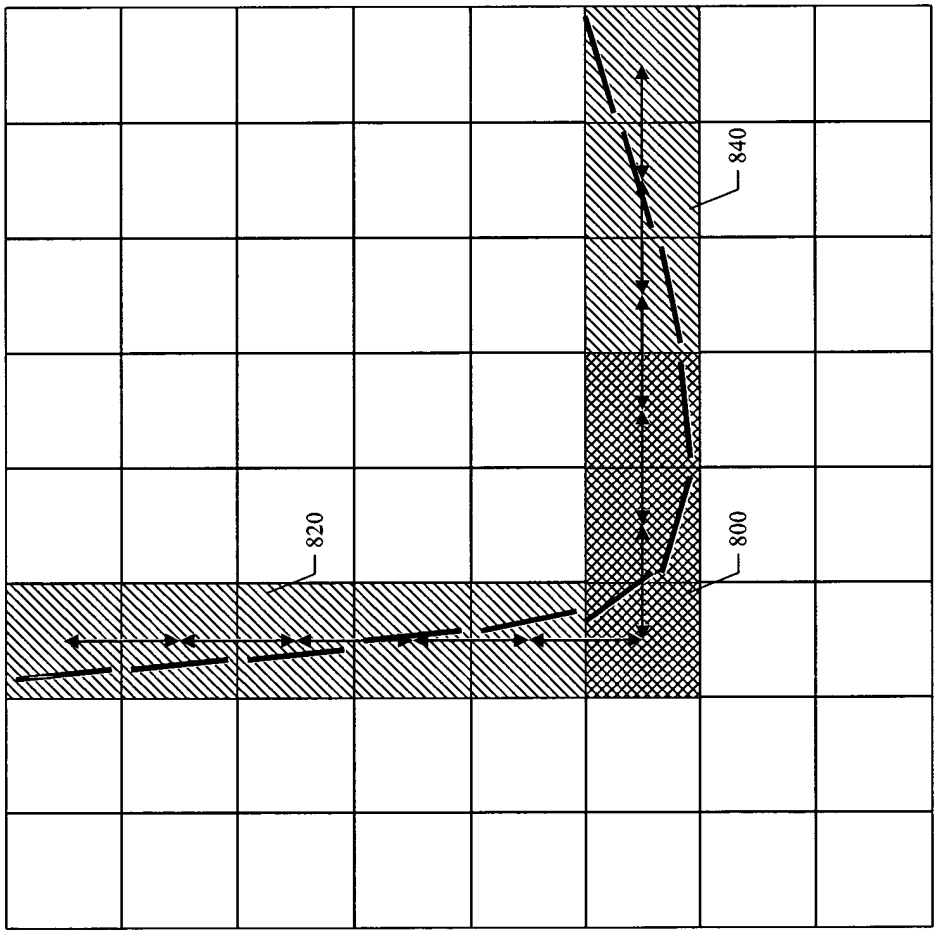

Figure 8

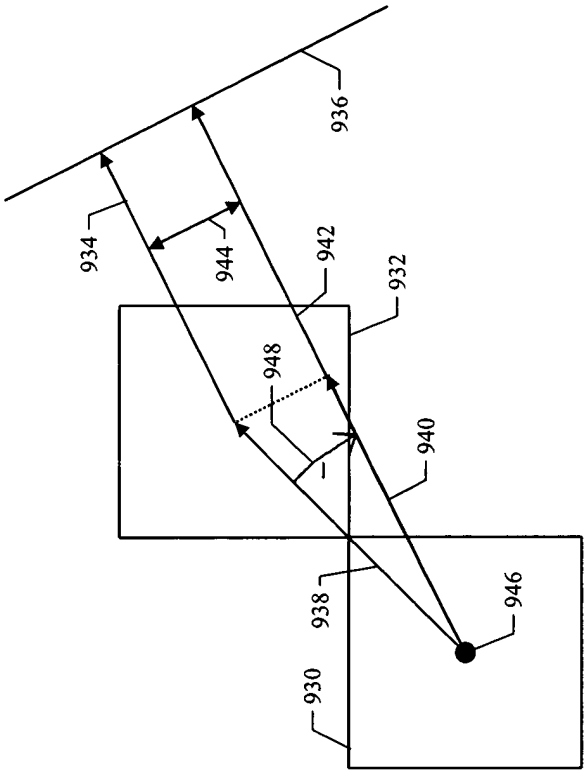

Figure 9b

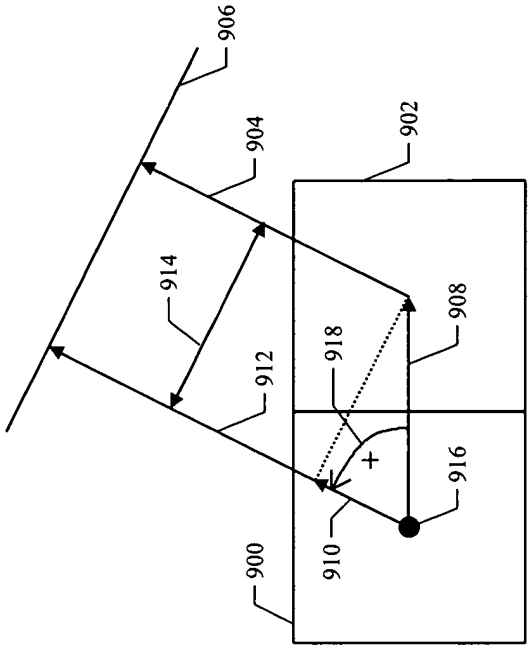

Figure 9a

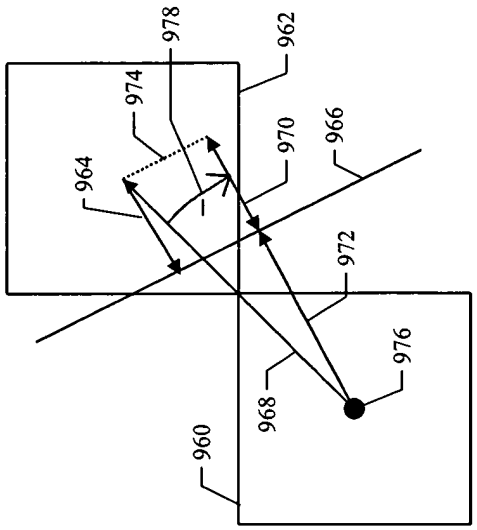

Figure 9c

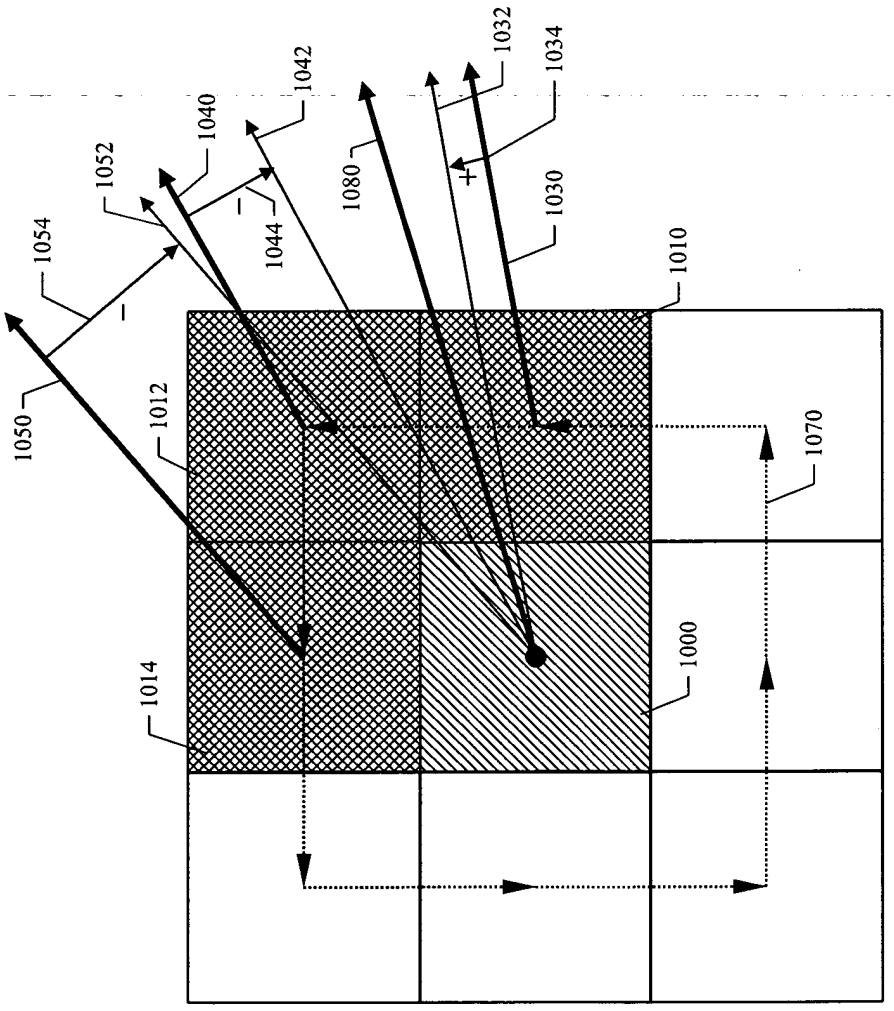
1032
1034
1042
1040
1052
1080
1030
1044
1054
1010
1012
1050
1070
1000
1014

Figure 10

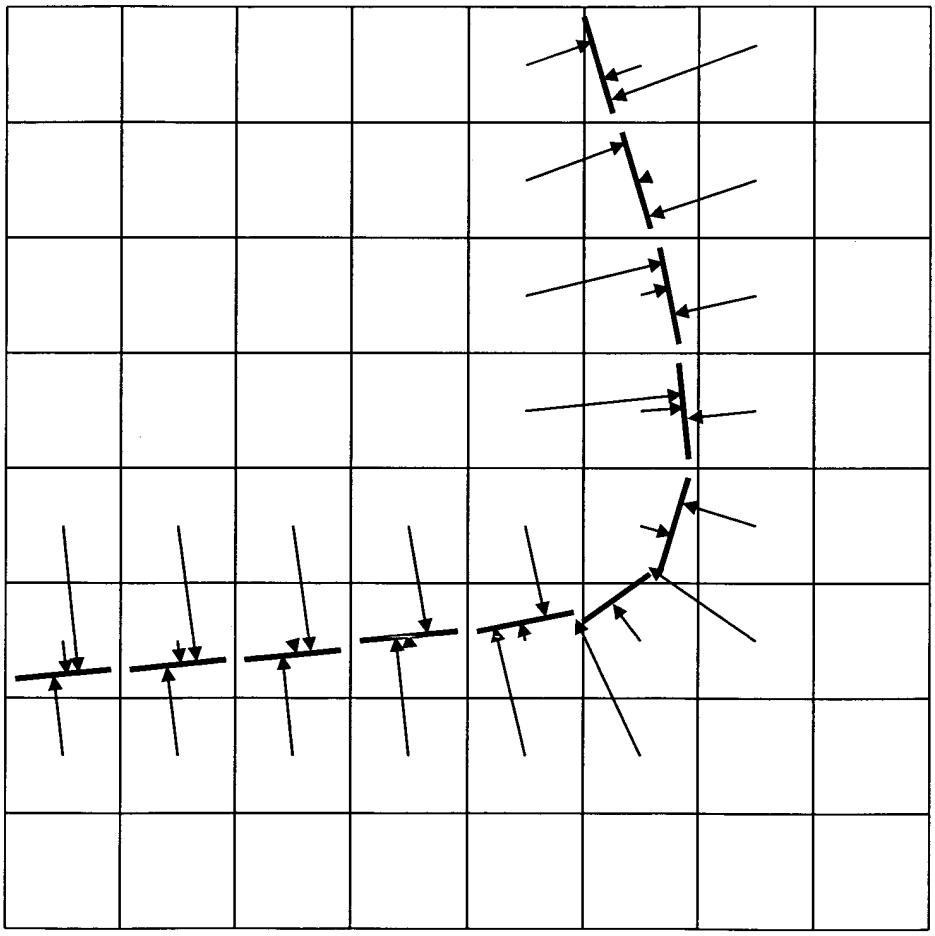

Figure 11

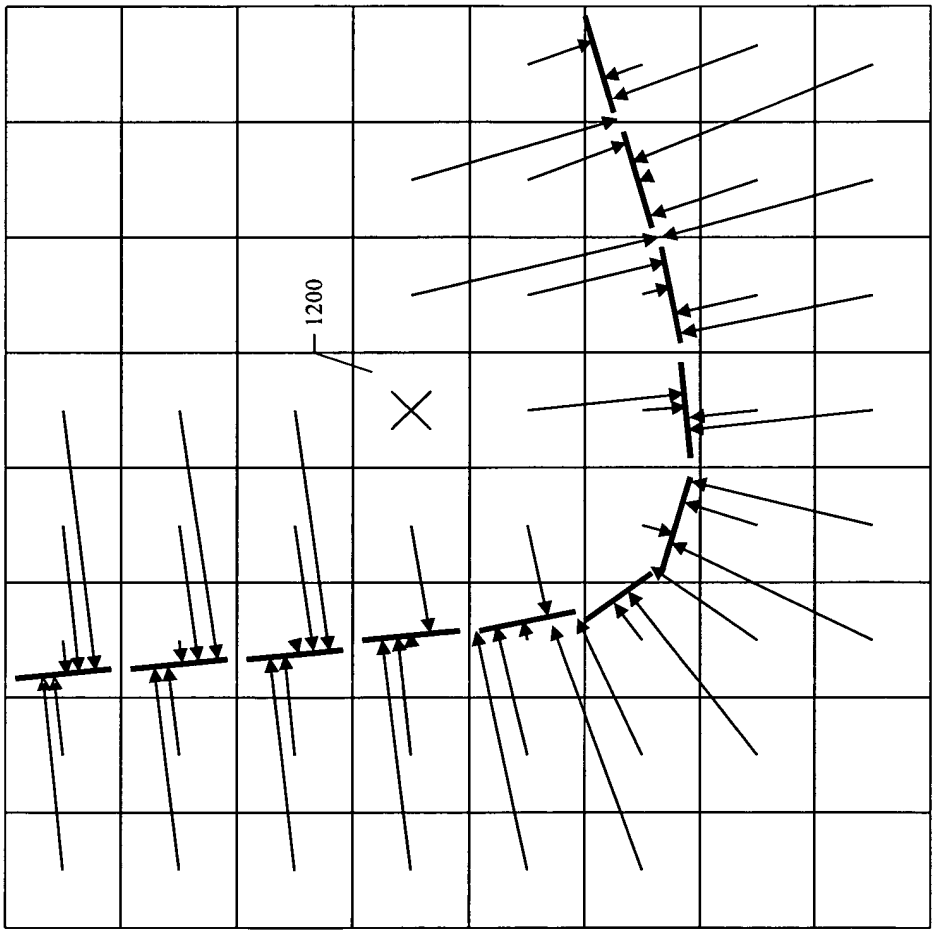

Figure 12

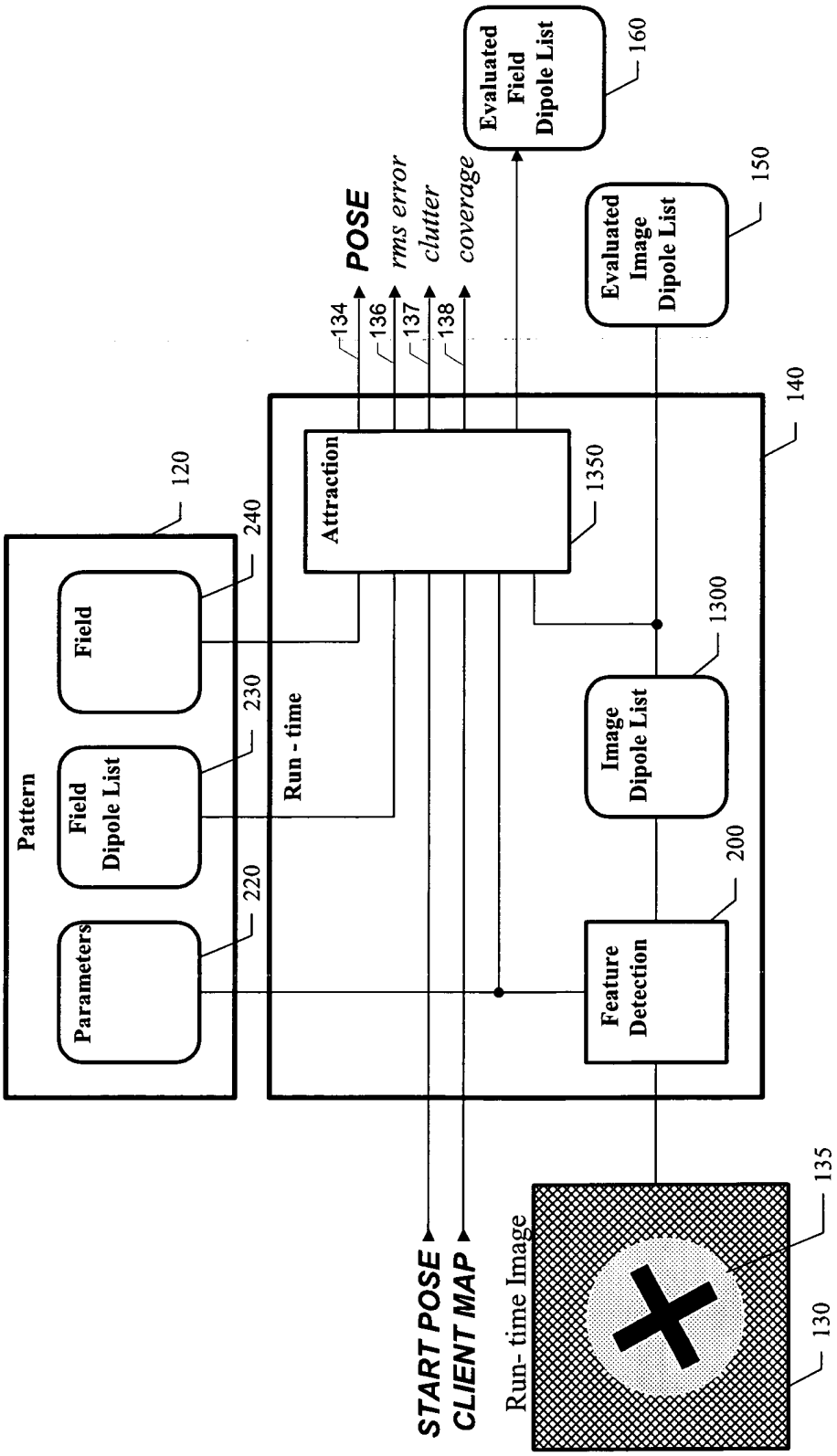
Evaluated Field Dipole List
160
Evaluated Image Dipole List
150
POSE
rms error
clutter
coverage
134
136
137
138
140
Attraction
1350
120
240
Field
230
Field Dipole List
Run - time
1300
Image Dipole List
Pattern
220
Parameters
200
Feature Detection
START POSE
CLIENT MAP
Run- time Image
135
130

Figure 13

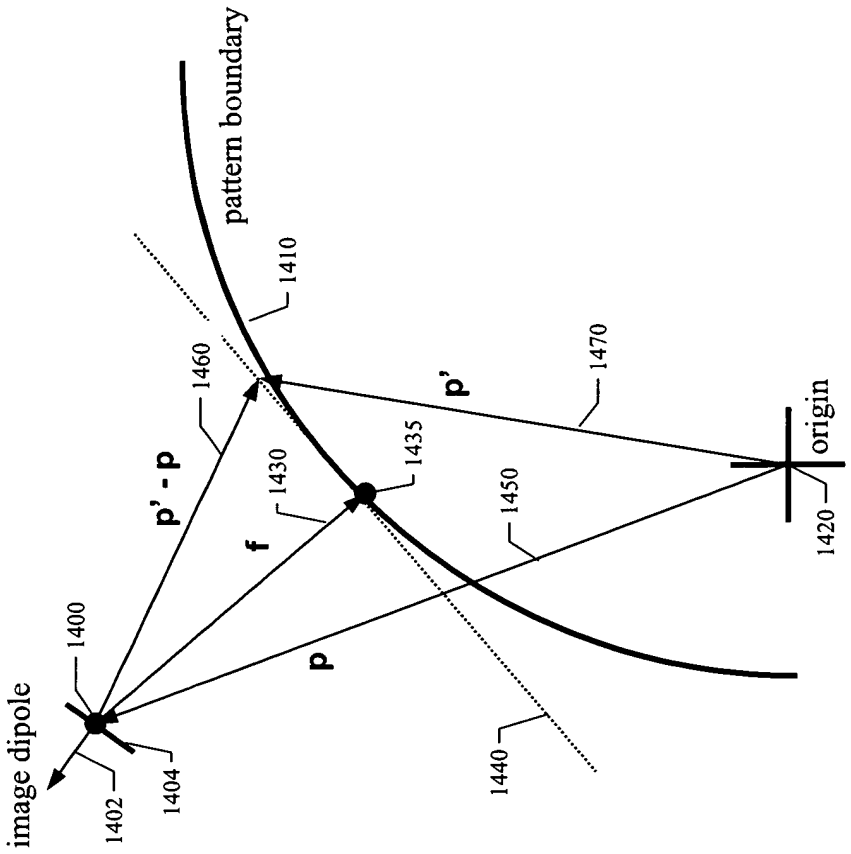
image dipole
1400
1402
1404
p' - p
1460
f
1430
p
1410
pattern boundary
1435
1450
1440
p'
1470
origin
1420

Figure 14

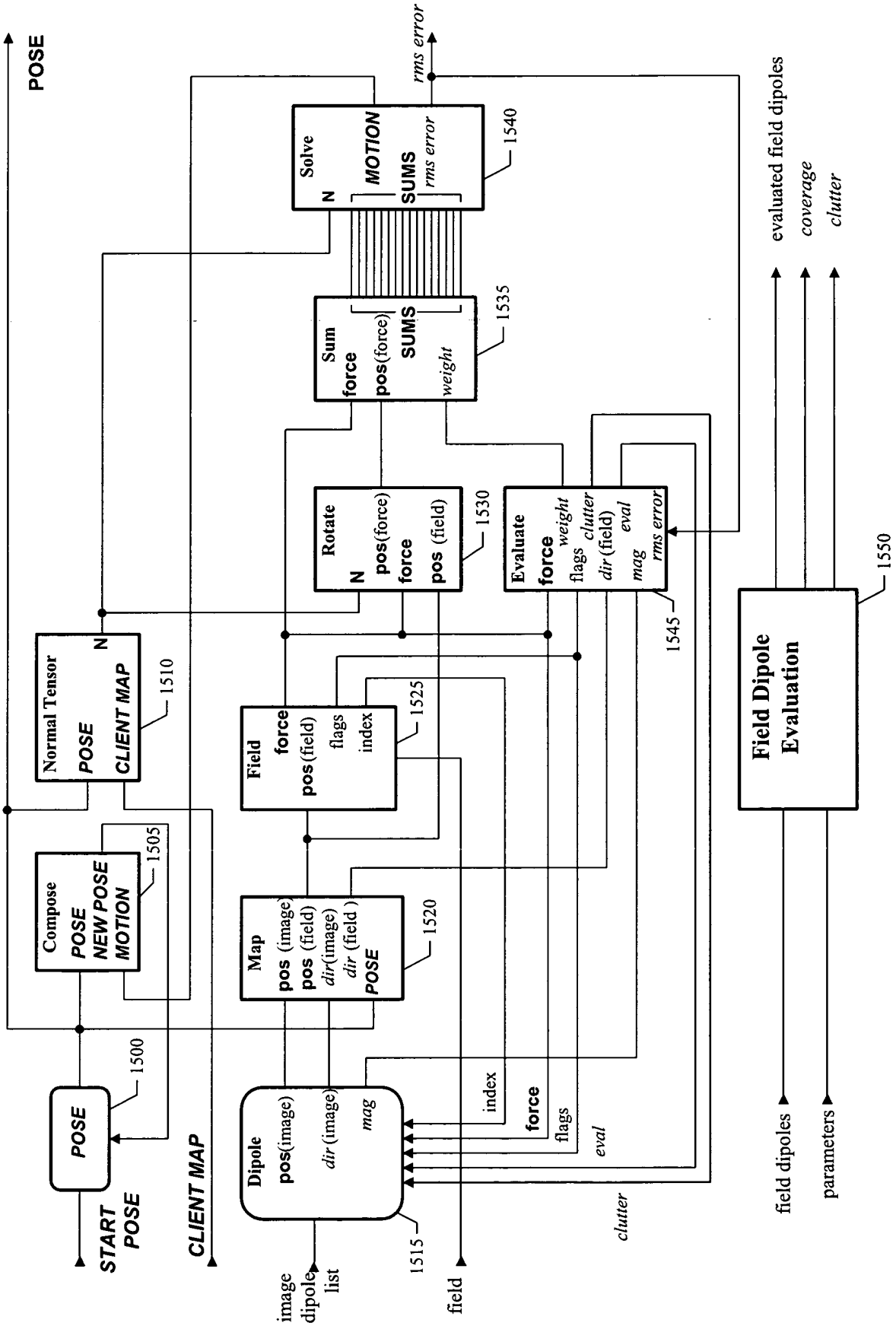
POSE
rms error
Solve
N
MOTION
SUMS
rms error
1540
Sum
force
pos(force)
SUMS
weight
1535
Rotate
N
pos(force)
force
pos (field)
1530
Evaluate
force
weight
flags
clutter
dir (field)
eval
mag
rms error
1545
evaluated field dipoles
coverage
clutter
Field Dipole Evaluation
1550
Normal Tensor
N
POSE
CLIENT MAP
1510
Field
force
pos (field)
flags
index
1525
Compose
POSE
NEW POSE
MOTION
1505
Map
pos (image)
pos (field)
dir (image)
dir (field)
POSE
1520
POSE
1500
Dipole
pos(image)
dir (image)
mag
index
force
flags
eval
clutter
1515
START POSE
CLIENT MAP
image dipole list
field
field dipoles
parameters

Figure 15

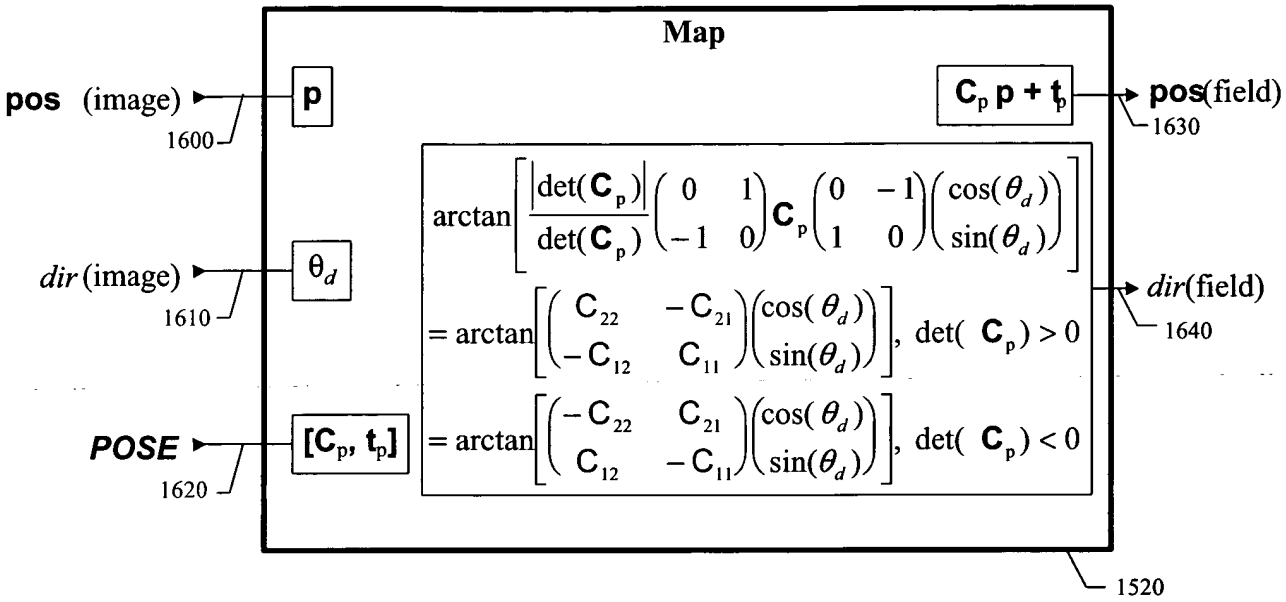

Figure 16

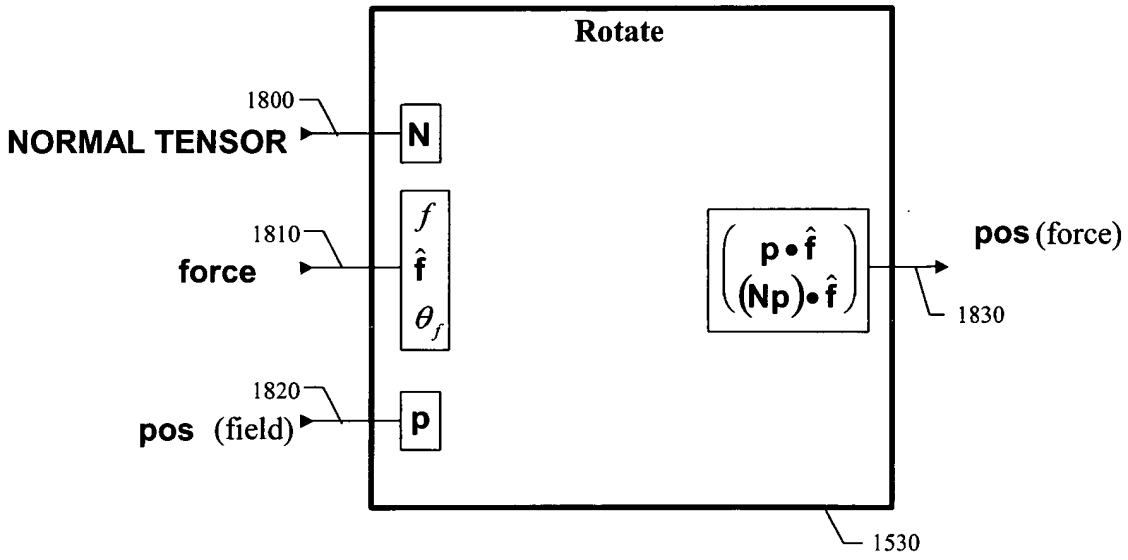

Figure 18

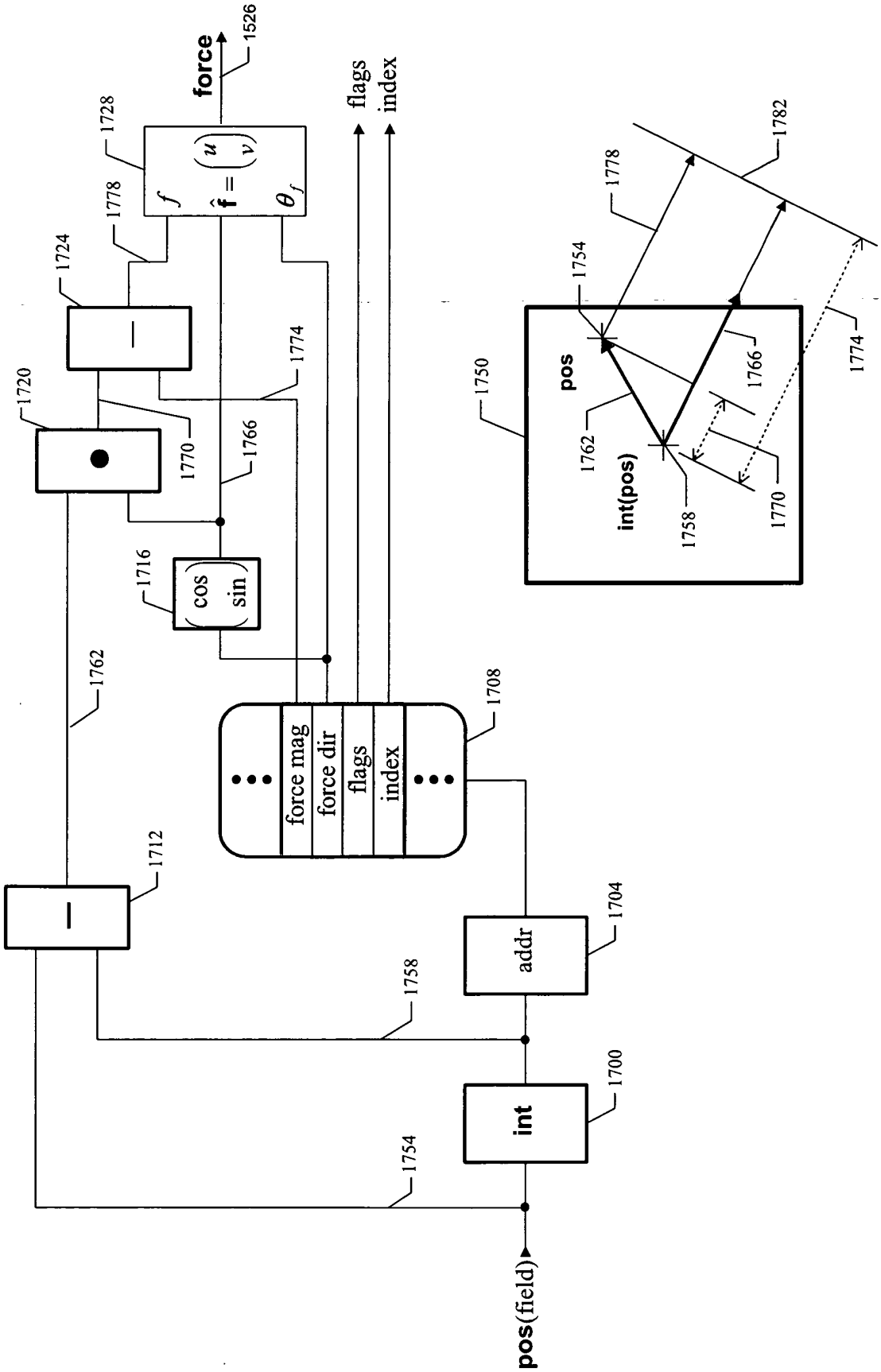
pos(field)
int
1700
addr
1704
1758
1754
1712
1762
force mag
force dir
flags
index
1708
cos
sin
1716
1720
1724
1728
1778
1774
1766
1770
force
1526
flags
index
1782
1778
1754
1774
1750
pos
1762
int(pos)
1758
1766
1770

Figure 17

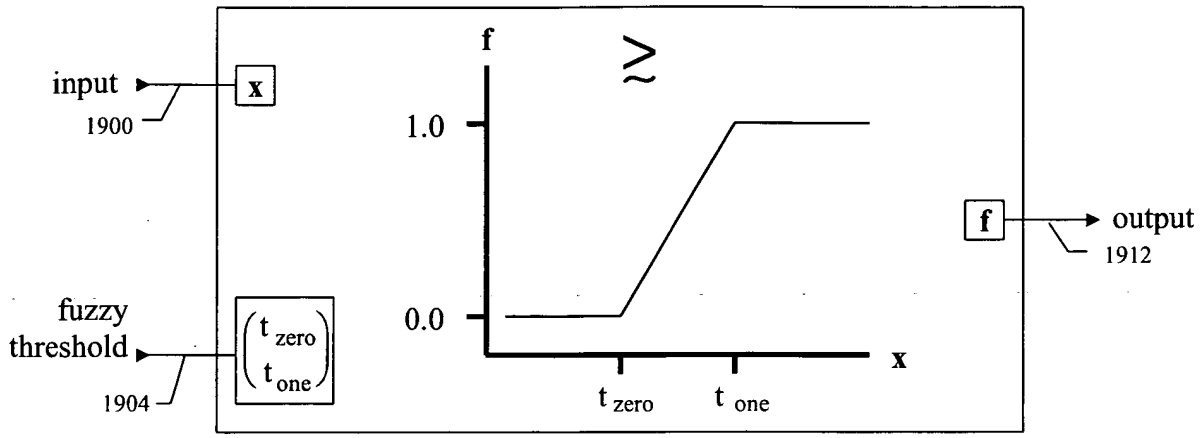

Figure 19a

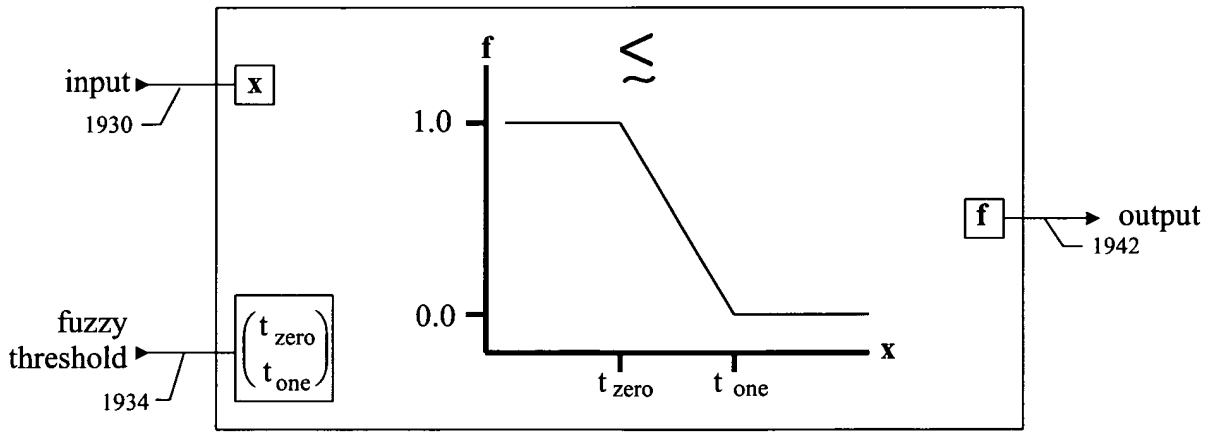

Figure 19b

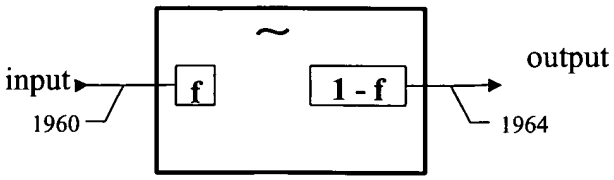

Figure 19c

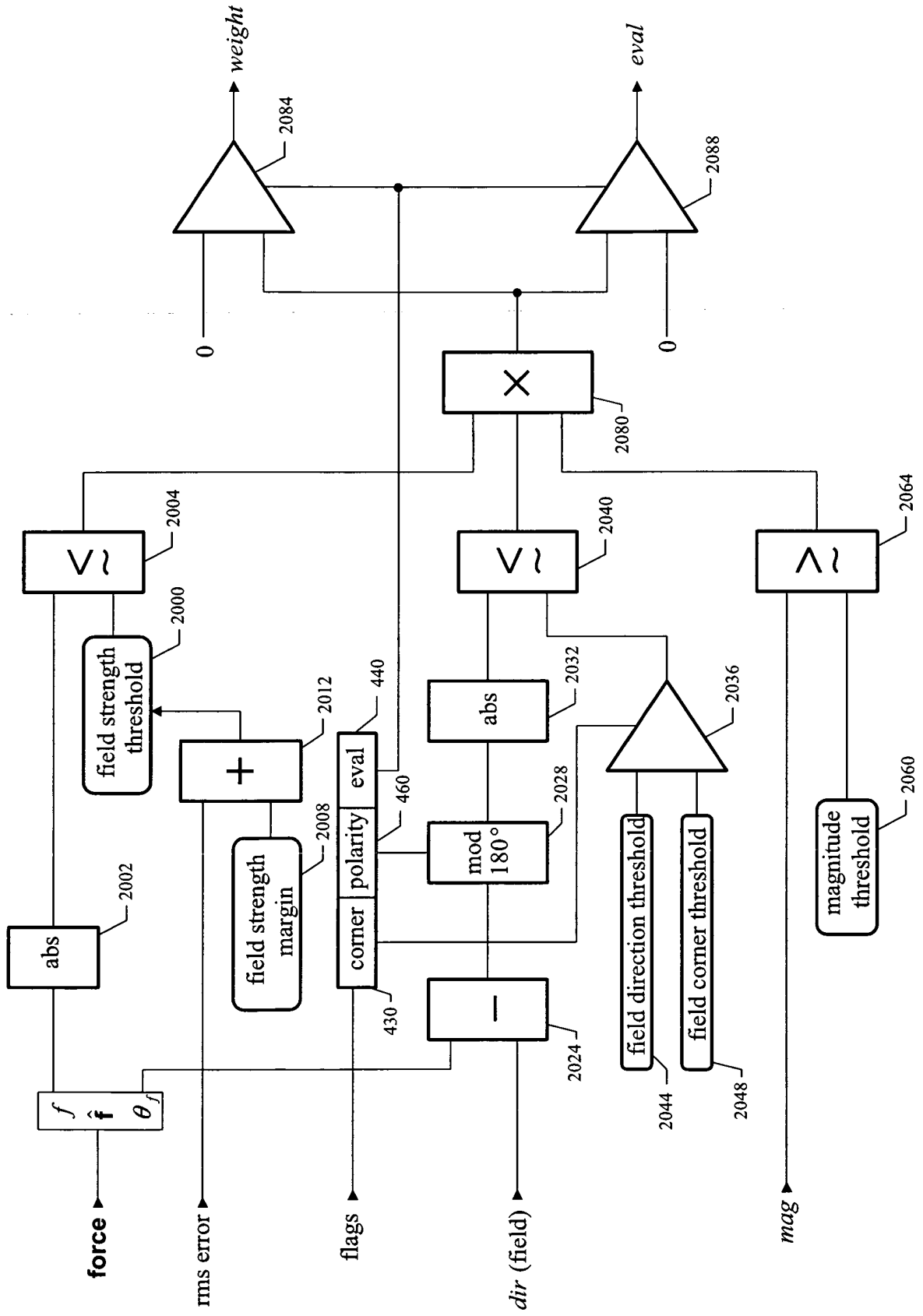
weight
eval
2084
2088
0
0
×
2080
2004
2040
2064
2000
2012
440
2032
2036
abs
field strength threshold
+
eval
polarity
corner
460
mod 180°
2028
2008
2002
field strength margin
abs
field direction threshold
field corner threshold
magnitude threshold
2060
430
−
2024
2044
2048
f
f̂
θf
force
rms error
flags
dir (field)
mag

Figure 20a

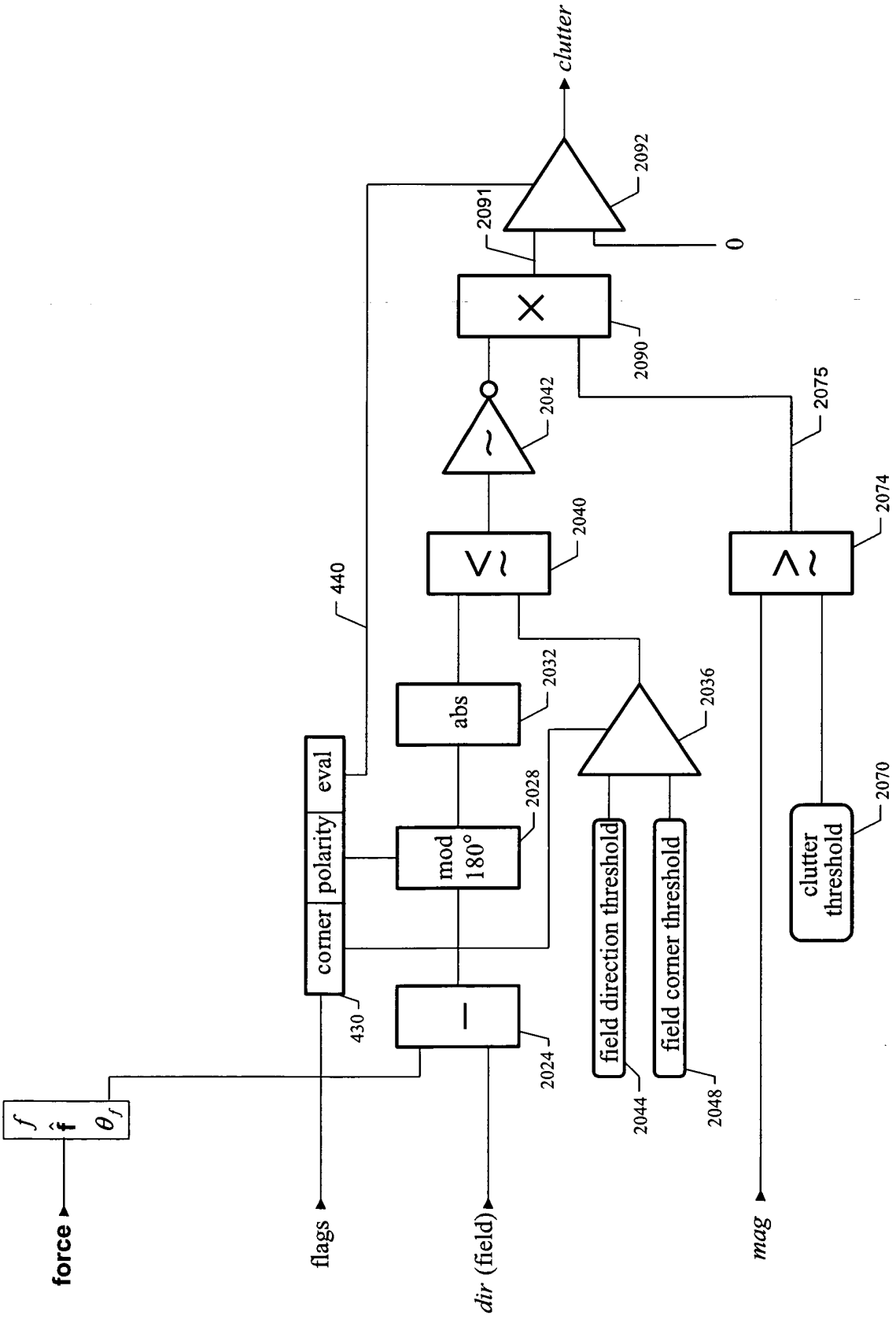
clutter
2092
2091
0
2090
2075
2042
2040
2074
440
2032
2036
2028
2044
2048
2070
2024
430
flags
dir (field)
mag
force
eval
polarity
corner
abs
mod 180°
field direction threshold
field corner threshold
clutter threshold

Figure 20b

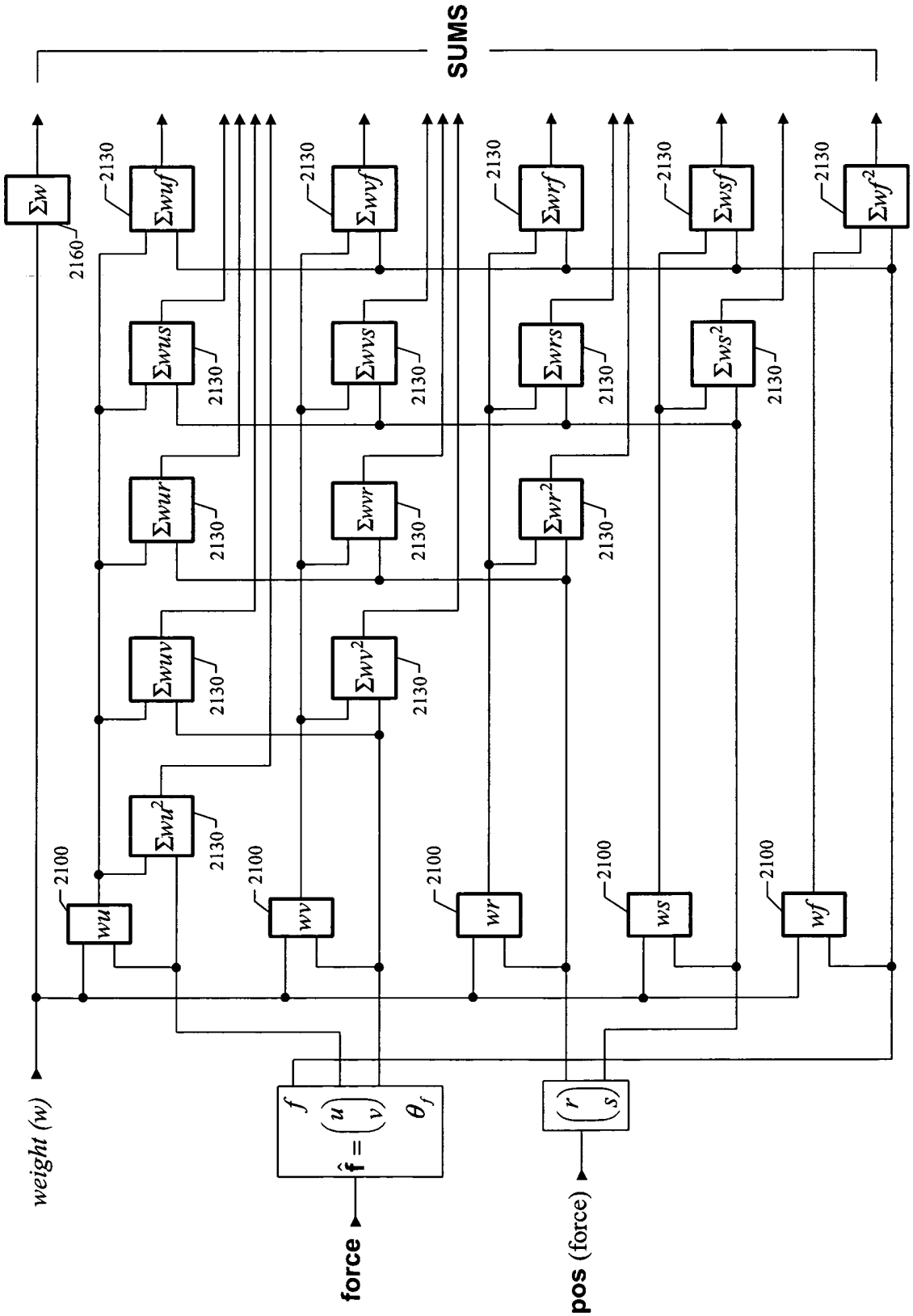
SUMS
Σw
2160
Σwuf
Σwvf
Σwrf
Σwsf
Σwf²
Σwus
Σwvs
Σwrs
Σws²
Σwur
Σwvr
Σwr²
Σwuv
Σwv²
Σwu²
2130
2100
wu
wv
wr
ws
wf
weight (w)
force
pos (force)

Figure 21

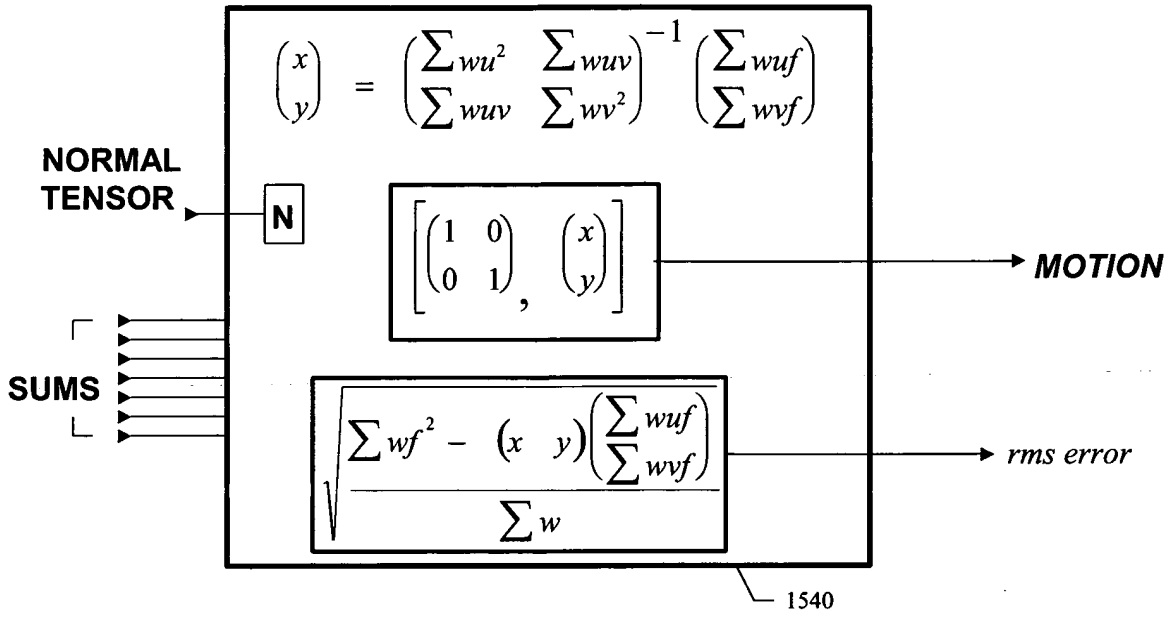

Figure 22a

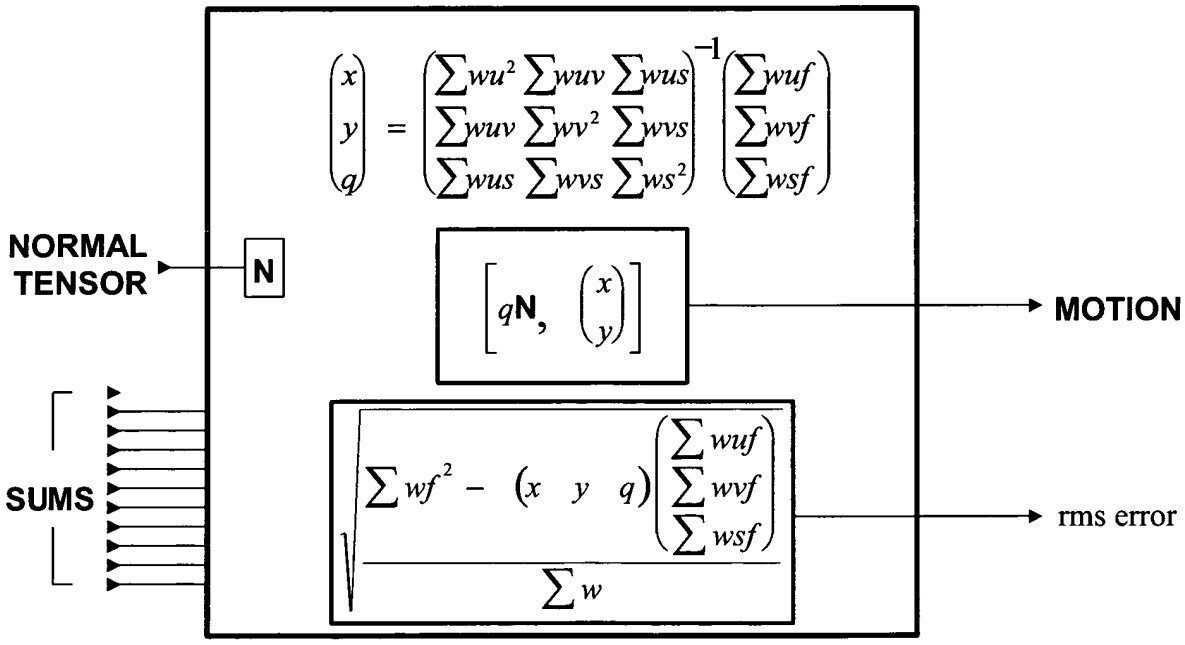

Figure 22b

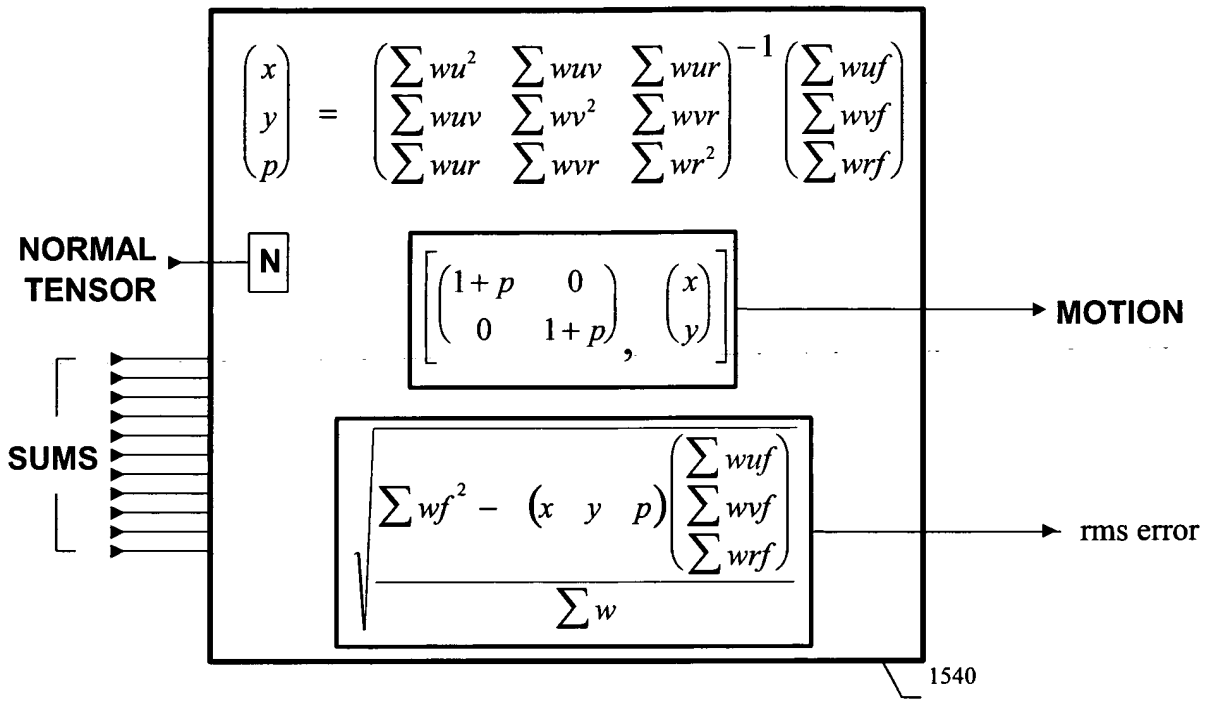

Figure 22c

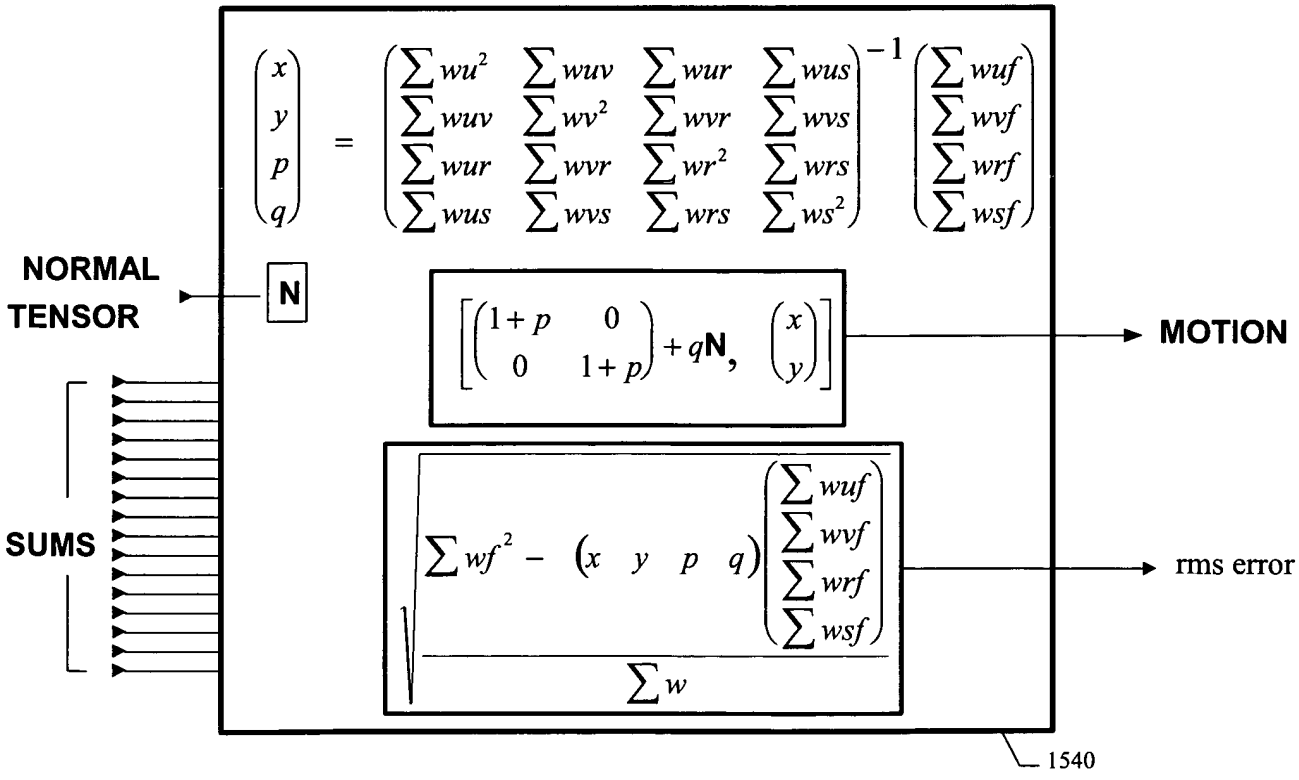

Figure 22d

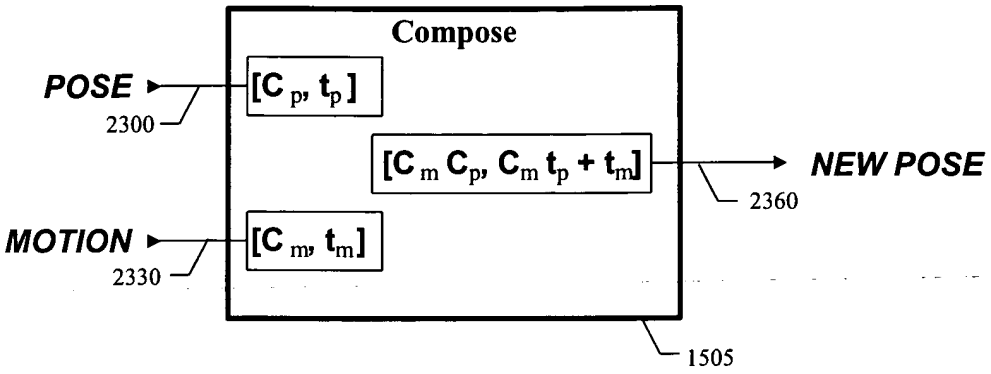

Figure 23

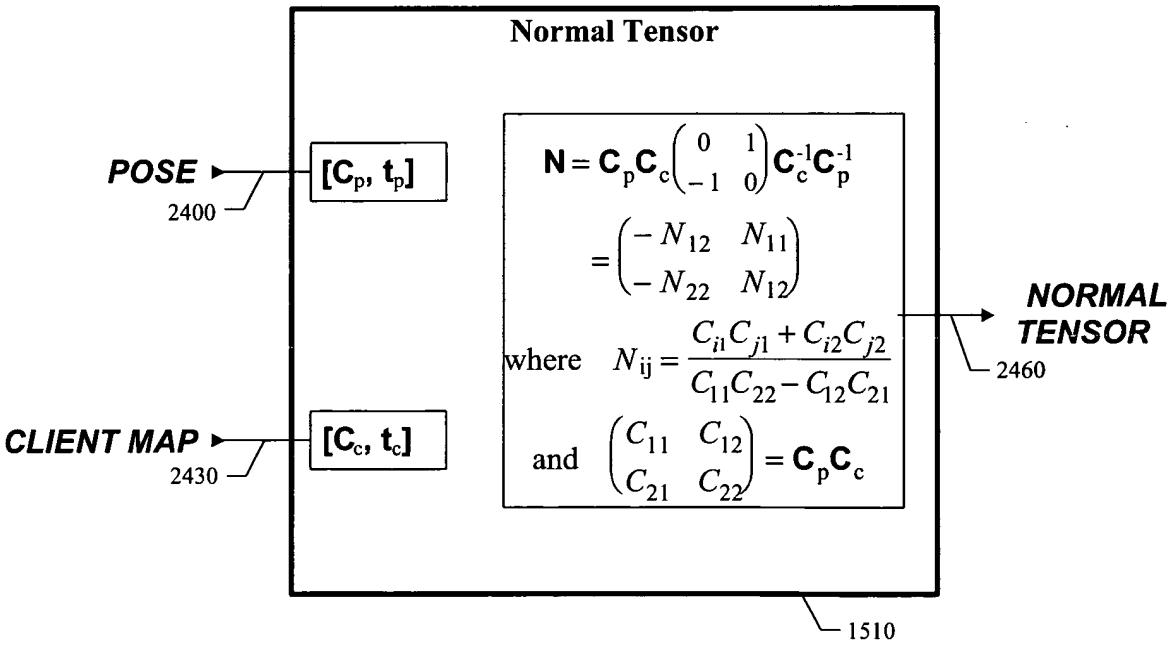

Figure 24

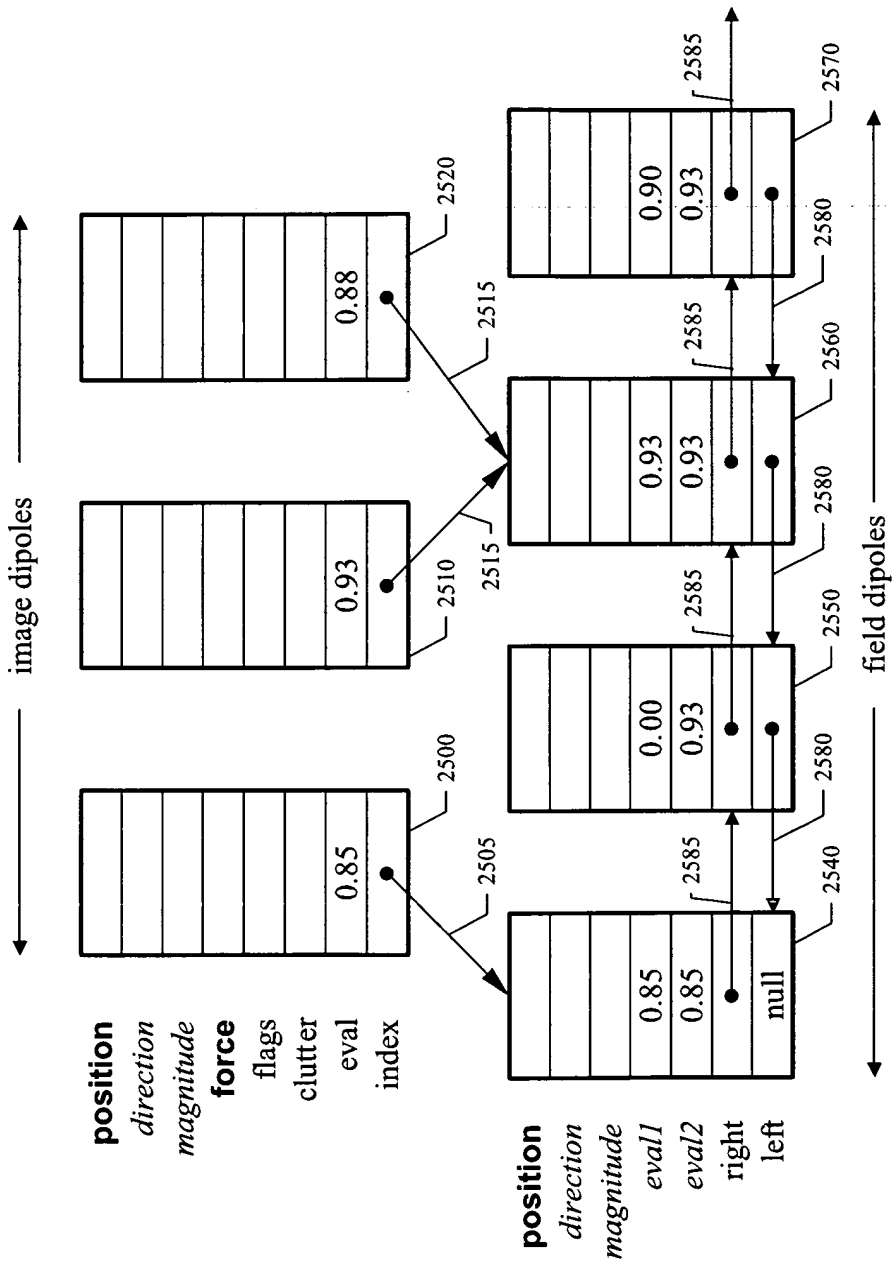
image dipoles
position
direction
magnitude
force
flags
clutter
eval
index
0.85
0.93
0.88
2500
2505
2510
2515
2520
field dipoles
position
direction
magnitude
eval1
eval2
right
left
0.85
0.85
null
0.00
0.93
0.93
0.93
0.90
0.93
2540
2550
2560
2570
2580
2585

Figure 25

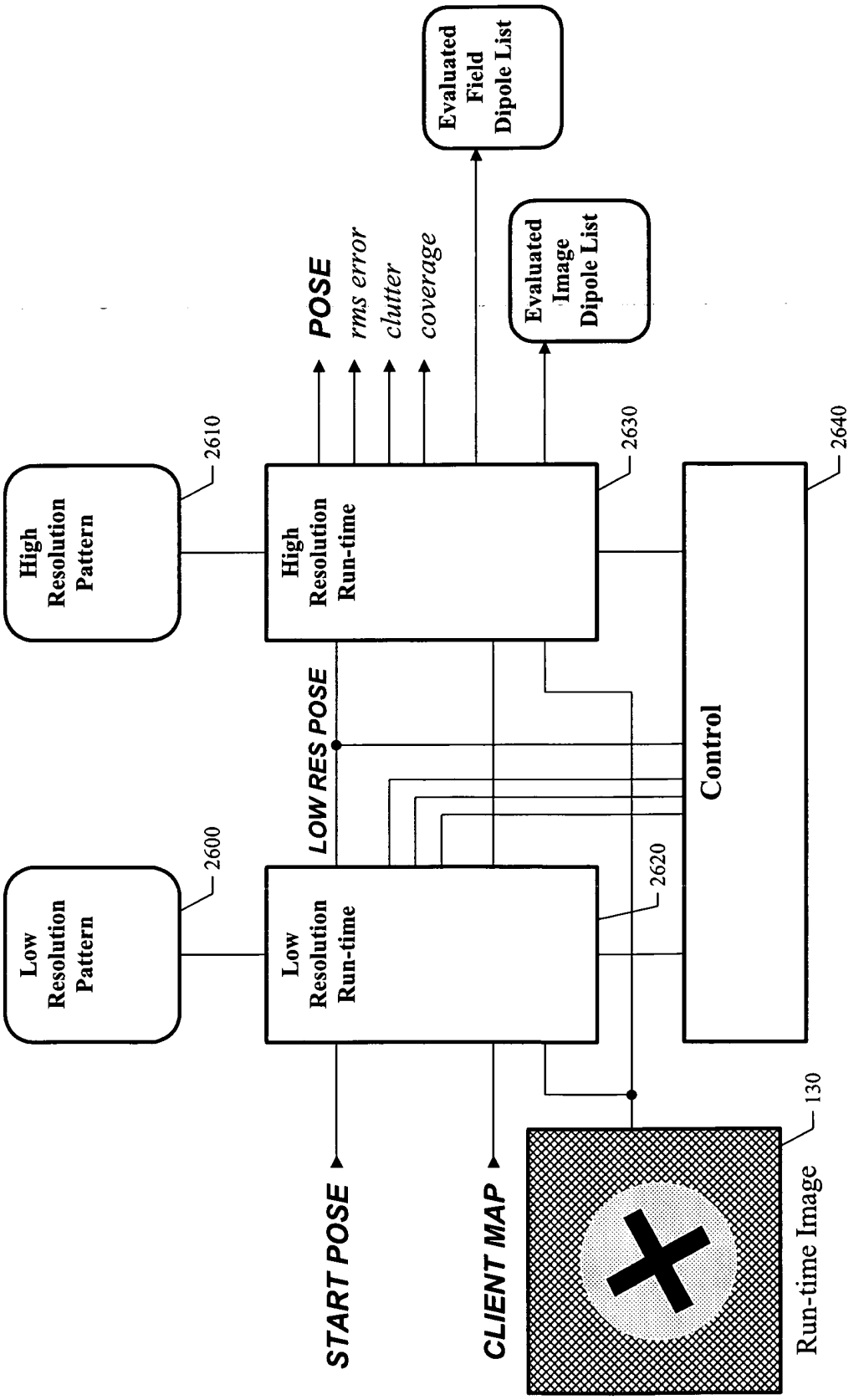
Evaluated Field Dipole List
Evaluated Image Dipole List
POSE
rms error
clutter
coverage
High Resolution Pattern
2610
High Resolution Run-time
2630
2640
Control
LOW RES POSE
Low Resolution Pattern
2600
Low Resolution Run-time
2620
START POSE
CLIENT MAP
130
Run-time Image

Figure 26

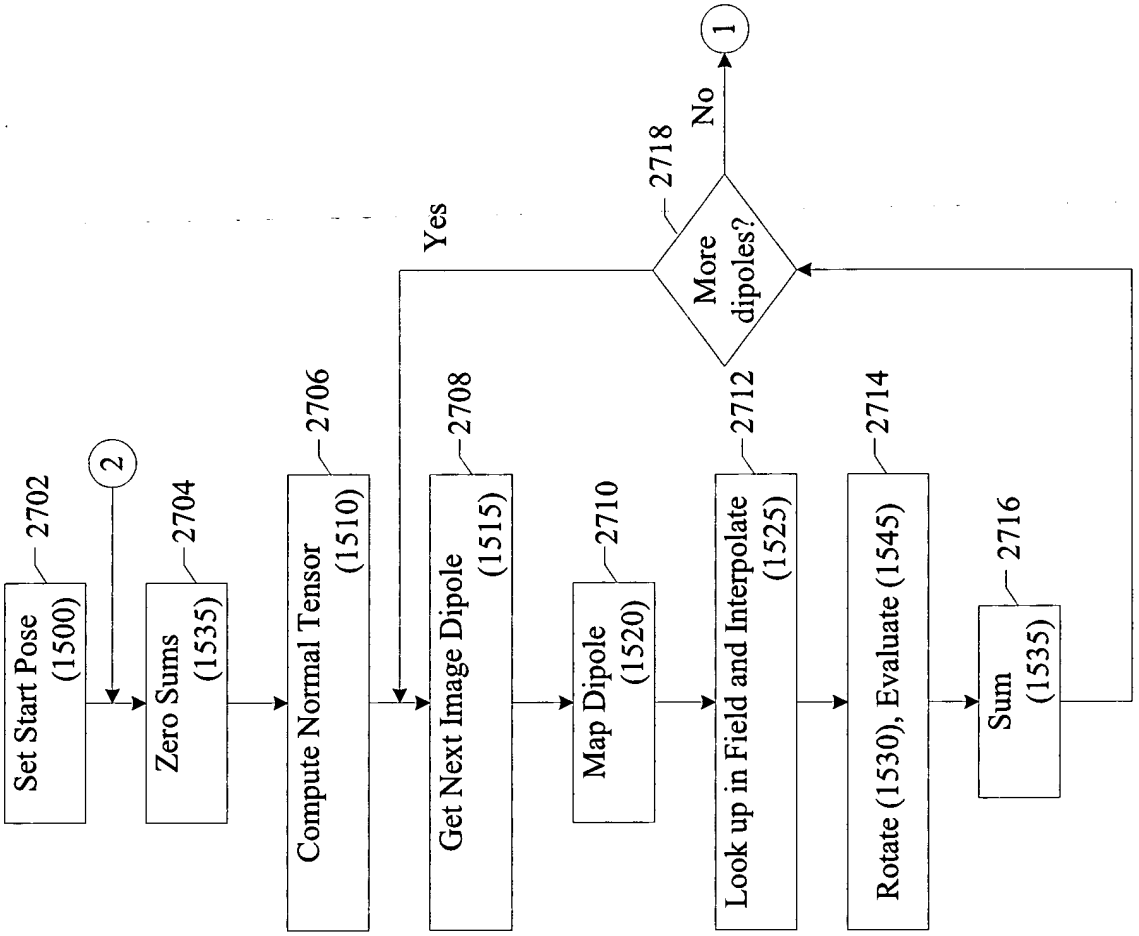
Set Start Pose (1500)
2702
2
Zero Sums (1535)
2704
Compute Normal Tensor (1510)
2706
Get Next Image Dipole (1515)
2708
Map Dipole (1520)
2710
Look up in Field and Interpolate (1525)
2712
Rotate (1530), Evaluate (1545)
2714
Sum (1535)
2716
More dipoles?
2718
Yes
No
1

Figure 27a

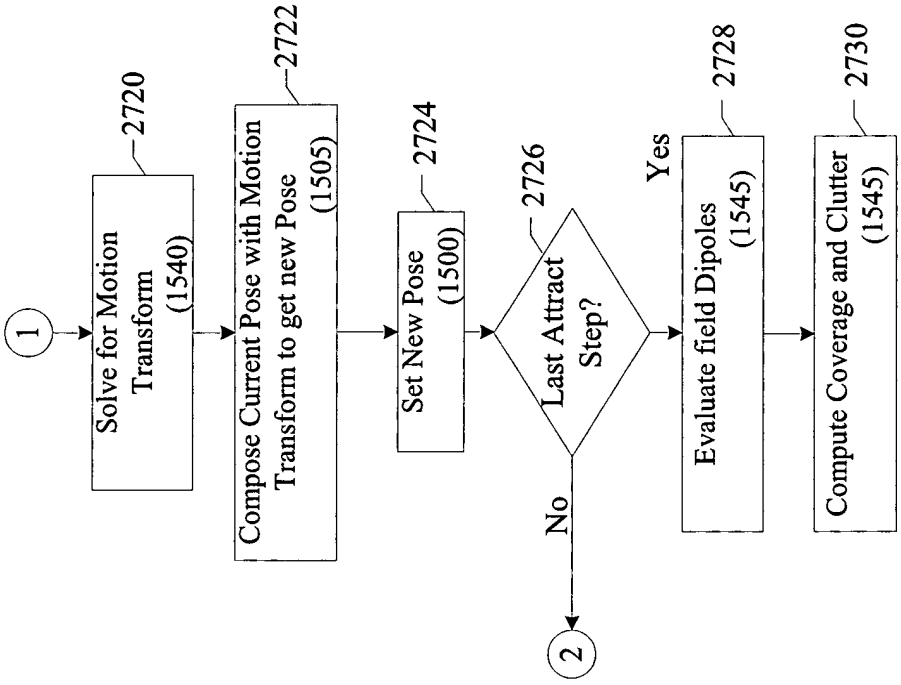
1
Solve for Motion Transform (1540)
2720
Compose Current Pose with Motion Transform to get new Pose (1505)
2722
Set New Pose (1500)
2724
Last Attract Step?
2726
No
Yes
2
Evaluate field Dipoles (1545)
2728
Compute Coverage and Clutter (1545)
2730

Figure 27b

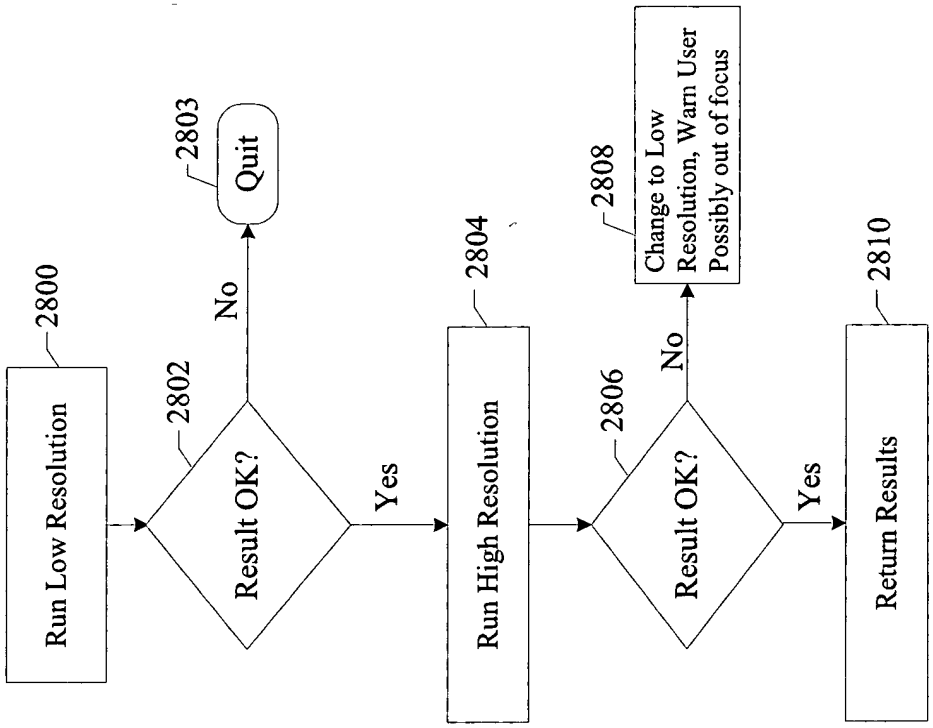
2800
Run Low Resolution
2802
Result OK?
No
2803
Quit
Yes
2804
Run High Resolution
2806
Result OK?
No
2808
Change to Low Resolution, Warn User Possibly out of focus
Yes
2810
Return Results

Figure 28